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Crude Oil To Chemicals Complexes

A Study by Richardson Lawrie Associates

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WADE MARITIME GROUP

What is Crude Oil to Chemicals Complex

For much of the 20th century, refineries were engineered primarily to maximize transport fuels. Early plants relied heavily on atmospheric distillation to separate crude into basic fractions, supported by thermal cracking to increase gasoline and middle-distillate yields. As fuel demand expanded, this fuels-first configuration dominated refinery investment and operating strategy.

By the 1970s, the industry began introducing limited petrochemical integration. Some facilities added units and processing pathways that enabled a modest uplift in chemical production, but the overall output remained strongly fuel weighted. Typical integrated sites in that era could convert only around 10% to 20% of each barrel of crude into chemical products, with fuels still accounting for the bulk of value generation. Refinery design has evolved in line with shifting end-market demand.

Today, Crude Oil to Chemicals (COTC) complexes represent a major strategic pivot. Rather than treating chemicals as a secondary by-product, these assets are designed to maximize petrochemical yields, often producing roughly 40% to 70% chemical output from crude, depending on configuration. Electrification and fuel efficiency gains are eroding long-term growth prospects for gasoline and diesel, while decarbonization pressures are raising the cost of carbon-intensive fuel production and tightening operating margins. At the same time, petrochemical demand has remained comparatively resilient, underpinned by durable consumption of core building blocks like olefins and aromatics such as ethylene, propylene, benzene, toluene, and xylenes. These by-products are crucial feedstocks to produce plastics, synthetic fibres, packaging and industrial materials.

As a result, the industry is increasingly channelling investment toward highly integrated, chemicals focused configurations that can defend margins in a world of full of uncertainty, where supply chains can be under threat anytime.

Rising Significance

The global energy transition is increasingly reshaping downstream oil markets as long-term weakening demand for transport fuels and strengthening demand for petrochemical feedstocks takes the stage. On the fuels side, global oil demand, especially gasoline used in private vehicles is expected to peak within the next five to ten years. This is being driven by faster electrification, stronger shift towards sustainability, faster adoption of cleaner fuels and broader structural changes in mobility and consumer behaviour.

Petrochemicals are set to become the largest driver of global oil demand growth by 2030, overtaking gasoline and diesel. With this, the refiners face a new challenge. Falling demand has caused lower throughputs and weaker profit margins and are likely to pressure refinery utilization rates, with the greatest impact concentrated in regions already struggling with demand maturity and high operating costs, particularly Western Europe and some parts of Asia like China. In this scenario, average utilization for a refiner could fall from around the 80% range toward the 70% range or even low. These pressures are expected to accelerate capacity rationalization. Due to such structural change, the refiners are integrating refineries with petrochemical production to enhance gross refining margins.

Less complex, fuel-oriented refineries, typically those with limited upgrading and retrofitting capabilities and weaker integration into petrochemical chains are most exposed, as they have fewer options to shift yields or capture higher value products. In contrast, more complex and petrochemically integrated sites may be better positioned to adapt by increasing exposure to

feedstocks and value-added chemical outputs. Overall, the transition implies a structurally more competitive and consolidation prone refining landscape.

Ongoing geopolitical tensions have heightened refiners' and petrochemical producers' focus on supply chain security, prompting more cautious sourcing and risk planning. As part of this forward looking strategy, investment is already accelerating in regions such as China to strengthen and integrate supply networks.

The China Story

China currently stands as the biggest importer of crude oil worldwide. China has mainly been sourcing its crude oil from Russia, Iran and Saudi Arabia so far. Chinese imports of other byproducts like naphtha, propane, butane, ethylene have also remained rampant during the past four to five years. China heavily requires these high value by-products to cater to the feedstock requirements of its refineries further to produce petrochemicals, polymers and intermediates. China's petrochemical demand is driven by rising incomes and continued growth in production of plastics and synthetic fibres which is typically exported into Southeast Asian nations.

Moreso, the recent 15th five year plan announced by the Chinese government in 2025 calls for increasing domestic consumption. Policies within the plan favour raising household incomes, upgrading consumption and expanding service sector spending support.

The drivers for Chinese domestic consumption include packaging, consumer goods and hygiene chemicals, cosmetics and personal care ingredients, pharmaceuticals and healthcare materials along with other high value plastics for electronics and appliances.

Although China is strategically transitioning from a manufacturing driven economic model toward a service oriented and AI led growth framework, its manufacturing dominated ecosystem remains firmly intact and continues to play a central role in the broader economy.

China's chemical sector continues to grapple with structural oversupply, particularly across petrochemicals and polymers, despite broader economic ambitions to pivot toward services and AI-led growth economic model. The government's recently announced Anti-Involution policy aims to rationalize outdated and underperforming refineries and petrochemical assets by 2030, seeking to curb inefficient capacity and stabilize margins.

Nowhere is the imbalance more evident than in polyolefins. Following aggressive capacity expansions, China's polyethylene and polypropylene markets have shifted from tight import dependence to chronic surplus. The country, once the world's largest polymer importer, is increasingly exporting polypropylene, polyethylene (all grades), poly-vinyl chloride, polyamide/nylons, and polystyrene primarily into Southeast Asia, including Vietnam and Indonesia leveraging advantages under the China-ASEAN free trade agreement. This growing Chinese export wave is displacing traditional suppliers from the Middle East and Northeast Asia.

At the same time, commodity chemical imports have softened but not disappeared. Most are state-owned facilities which operate at relatively low utilization rates of 65% to 70%, slowing domestic supply adjustments. Consequently, China continues to import selected volumes, particularly from Saudi Arabia, Iran, and Oman, to balance its feedstock and product slate requirements.

Talking of the global COTC investments, China has taken the lead with a total of 150 million tonnes/year of operating or planned capacity. China added three integrated COTC complexes at Dalian with 300,000 b/d, Zhoushan with 400,000 b/d, Linyungang with 320,000 b/d of refining capacity. Facilities produce more than 15 million tonnes/year paraxylene along with some olefin derivatives. The refineries also include back integration from polyesters.

A list of operating and planned COTC complexes in China has been provided in the **Table 1**.

Chinese investments into COTC complexes led by Hengli Petrochemical, Shenghong Petrochemical and Shandong Yulong Petrochemical have so far exceeded $60 billion.

Other planned integration-projects involve Middle Eastern giants such as Saudi Aramco and SABIC few of which are listed below.

- Saudi Aramco-Fujian Sinopec: A joint venture to build and run a $9.8 billion integrated refining and petrochemical complexes in Fujian, China, set to be completed by 2030.
- Huajin-Aramco Petrochemical: Aramco alongside NORINCO group is developing a $10 billion COTC complex which includes 300,000 b/d refinery. The project is projected to be operational by 2026.
- SABIC: Aramco's subsidiary announced investments worth $6.4 billion in a petrochemical complex in Fujian.

Table 1 List of Operating and Planned COTC Complexes in China

Sr. No.	Project Name	Location	Sartup	Conversion to Chemicals	Investments
1	Zhejiang Petroleum and Chemical	Zhoushan, China	Phase 1: 2019	Phase 1: ~45%	Phase 1: $12.0 billion
			Phase 2: 2022	Phase 2: ~70% (combined with phase 1)	Phase 2: $12.0 billion
2	Hengyi Group	Pulau Muara Besar, Brunei	Phase 1: 2019	Phase 1: ~40%	Phase 1: $ 3.5 billion
			Phase 2: 2027	Phase 2: Unannounced	Phase 2: $ 9.0 billion
3	Hengli Petrochemicals	Dalian, China	2020	~40%	$ 11.4 billion
4	Shenghong Petrochemicals	Lianyungang, China	2022	~60%	$ 11.0 billion
5	Shandong Yulong Petrochemical	Yulong Island, China	2024	~50%	$ 17.8 billion

As high value chemicals such as ethylene, propylene, and paraxylene show stronger structural demand growth than fuels, refiners are increasingly deploying highly integrated refinery-petrochemical configurations that can convert more than 40% of crude directly into chemicals.

Modern COTC configurations combine deep conversion technologies with olefins and aromatics production. These complexes integrate hydrocrackers, residue upgrading units, solvent de-asphalting, steam crackers, fluid catalytic cracking units, propane dehydrogenation and advanced aromatics units. The objective is to squeeze the bottom of the barrel, upgrading heavy residues into petrochemical intermediates. Conversion technologies such as H-Oil, HyK, Solvahl, and FLEXICOKING enable high residue upgrading, while aromatics focused routes maximize BTX (benzene, toluene and xylenes) yields through intensive integration. Alternatively, olefins oriented schemes emphasize propylene and light olefins production. A large portion of older refineries in China are currently exploring retrofit options as well.

Economic modelling indicates that chemical maximizing configurations generate stronger returns than traditional fuel-focused refineries in China, where capital costs are lower. This although, comes at a cost of aggressive capacity additions by major private-sector players who have contributed to global petrochemical oversupply and margin compression since last few years.

The said integration is said to happen in various stages and phases.

- First is moderate integration where just propylene is extracted from fluid catalytic cracking units.
- Second is medium integration where aromatics are extracted from gasoline.
- Third, high level integration where olefins are extracted from LPG and naphtha.

The two phases of COTC include;

- Phase 1: provides 40% to 50% chemicals yield by reconfiguring commercially proven technology. Retrofit of older refineries with steam crackers and hydrocrackers.
- Phase 2: provides 80% chemicals yield using developed technology. New grassroot refineries and expansion projects planned to handle crude oil directly with naphtha and LPG production through naphtha cracking.

The integration of refineries with chemicals production improves the feedstock security, enables easier blending of by-products into fuels, lower conversion costs and reduction in operating costs through shared utilities and infrastructure.

Technology innovation remains central to improving project economics. Advanced processes such as TC2C (Thermal Crude to Chemicals), Honeywell's NEP (Naphtha to Ethane Propane), and direct catalytic crude to chemicals technologies aim to raise chemical conversion rates from crude oil to 75% to 80%, further recycle low value streams, and reduce capital intensity.

Despite cyclical margin pressures, the long-term outlook favours deeper refinery-petrochemical integration. Future competitiveness will depend on maximizing chemical yields, disciplined capital deployment, and embedding sustainability solutions such as renewable feedstocks and carbon capture, transforming refineries into integrated molecular platforms rather than just fuel-centric assets.

Projects elsewhere includes South Korea's S-Oil facility, which is expected to use TC2C technology, with an estimated chemical conversion of up to 70% from crude.

Impact on Regional Trade

China has lately increased its crude oil imports suggesting its beginning of the strategic shift to become self-reliant and secure its supply chains **(Figure 1: China Crude Oil Imports).** Accelerating investments in COTC complexes and refinery-petrochemical integration are structurally reshaping China's trade position in olefins and aromatics. By maximizing chemical yields from each barrel of crude, China is steadily reducing its reliance on imported commodity petrochemicals while increasing competitive export pressure across Asia.

The net effects are not expected to be immediate however, long term results, most probably post-2030, suggest less feedstock imports into China and more outbound competition from Chinese producers. China currently remains a net importer of feedstocks such as ethylene, naphtha and propane/butane with majority cargoes arriving from gulf nations (**Figure 2 Chinese Imports: Ethylene V LPG V Naphtha**).

Investments into large integrated COTC complexes are converting higher proportions of crude into olefins and BTX chains, contributing to oversupply in downstream aromatic derivatives and major polymers such as polypropylene. This will result in declining imports of polyethylene and polypropylene. Aromatics import dependence is likely to decline faster than olefins, given the strong integration of paraxylene, purified tetraphthalic acid, and other polyester chains. Going forward, aromatics imports are expected to become more opportunistic and arbitrage driven rather than structurally required.

Olefins trade, however, will not disappear. Demand remains broad and fragmented across packaging, automotive, appliances, and infrastructure applications. While China's capacity additions are significant, gaps remain in specialty grades, certain C4/C5 streams and performance grade polymers. Imports may persist in these niches, especially when domestic operating rates fluctuate.

As China's net imports are projected to erode post-2030, traditional exporters, particularly in Northeast Asia and the Middle East could redirect volumes toward alternate markets such as India, Southeast Asia, Turkey, Africa, and Latin America. This re-routing is expected to intensify competition across emerging import markets.

Figure 1 China Imports – Crude Oil

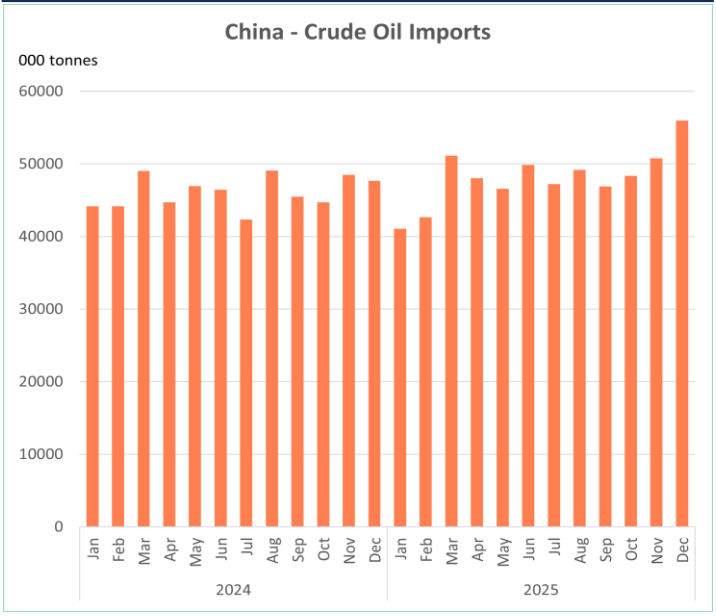
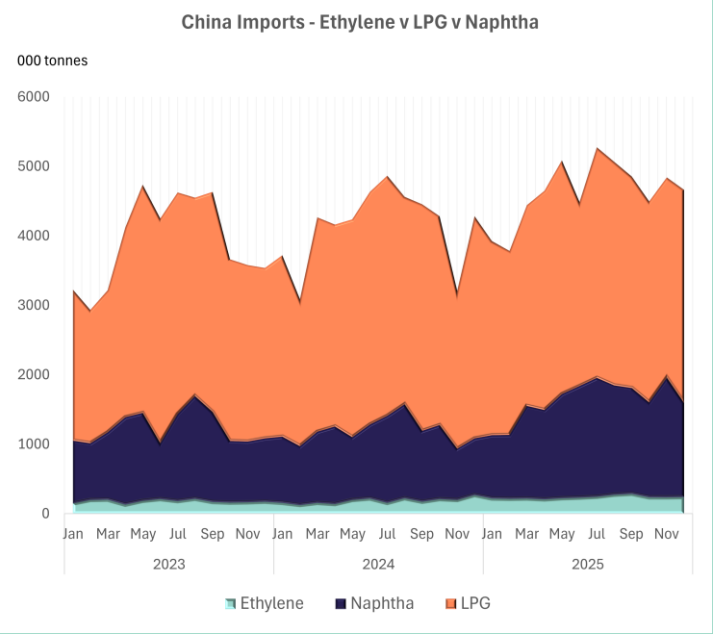


Figure 2 China Imports - Ethylene V LPG V Naphtha



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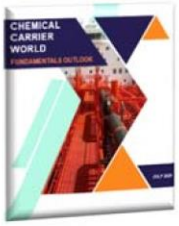

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